Ooi, J., & Puryer, J. (2018). What adverse effects does tooth-whitening have on dental restorations? *Faculty Dental Journal*, *9*(3), 92-98. https://doi.org/10.1308/rcsfdj.2018.92

What adverse effects does tooth whitening have on dental restorations? A literature review

Jessica Ooi [1]
Jo13671@my.bristol.ac.uk

James Puryer [2*]
James.puryer@bristol.ac.uk

1. Dental Undergraduate
Bristol Dental School
Lower Maudlin Street
Bristol
BS1 2LY
United Kingdom

2. Senior Clinical Teaching Fellow in Restorative Dentistry
Bristol Dental School
Lower Maudlin Street
Bristol
BS1 2LY
United Kingdom

***Corresponding author:**
James Puryer
Bristol Dental School
Lower Maudlin Street
Bristol
BS1 2LY
United Kingdom

Tel: +44 (0)117 342 9648
Fax: +44 (0)117 342 4443
E-mail: james.puryer@bristol.ac.uk

ABSTRACT

Introduction: The popularity of tooth whitening has increased in recent years as patients continue to seek treatments to improve their dental appearance. However, current literature suggests that tooth whitening may have adverse effects on both restorative materials and dental restorations. This literature review was carried out to summarise these possible adverse effects of tooth whitening on amalgam, composite, glass ionomer, porcelain and gold.

Method: Two electronic databases (PubMed and Web of Science Core Collection) were searched to find relevant literature from 2006-2017.

Findings: Existing literature has shown that bleaching may have a detrimental effect on restorative materials and that any adverse effects are likely to be material dependent. Much of the evidence currently available relates to *in-vitro* laboratory studies and methodology differences between studies have led to contradictory results. There is a need for more high quality, controlled *in-vivo* studies. Prior to carrying out tooth whitening procedures, clinicians should advise patients of possible changes to their existing dental restorations, and that in some cases, post-operative re-polishing or replacement of restorations may be required.

Keywords: Whitening Adverse Materials Restorations

INTRODUCTION

It is unsurprising that tooth whitening has become a popular dental treatment given that the demand for improved dental aesthetics has increased in recent years. In the UK, approximately 1 in 5 adults in a study population were dissatisfied with the colour of their teeth.[1] As a conservative technique, tooth whitening is widely accepted by both patients and dental professionals. Furthermore, it has been reported that it is the treatment which is most desired by patients who wish to improve their dental appearance.[2,3]

Current literature suggests that tooth whitening treatments, usually using carbamide peroxide (CP), hydrogen peroxide (HP) or a combination of both may have adverse effects on dental restorative materials. It is possible that the physical and/or chemical properties of restorative materials may be altered as a result of exposure to these active ingredients. Current literature has reported effects including an increased surface roughness of restorations, marginal breakdown, colour changes, crack propagation, metallic ion release from amalgam restorations and reduced tooth to restoration bond strength.[4,5] This literature review aims to summarise the adverse effects of tooth whitening on amalgam, composite, glass ionomer, porcelain and gold restorations and to determine if there are any clinical implications of which both clinicians and patients should be aware.

METHOD

To identify relevant articles for this review, two electronic databases (PubMed and Web of Science Core Collection) were searched from 2007 to 2016. The search queries used were:

- (“tooth whitening” OR “tooth bleaching”) AND (“composite” OR “amalgam” OR “glass ionomer” OR “porcelain” OR “gold” OR “dental restorations” OR “restorations”)

- (“tooth whitening” OR “tooth bleaching”) AND (“adverse effects” OR “negative effects”) AND (“composite” OR “amalgam” OR “glass ionomer” OR “porcelain” OR “gold” OR “dental restorations” OR “restorations”)

The initial search yielded 527 results. One researcher (J.O.) screened potential articles based upon the titles and abstracts, and together with the removal of duplicate titles, 401 titles were initially excluded. Considering the inclusion and exclusion criteria (Table 1) resulted

in a further 40 titles being excluded. The remaining full papers were scanned to assess suitability for inclusion in the review and 48 papers were finally included (Figure 1).

The papers included within the review were sorted into subgroups depending on the type of restorative material used (amalgam, porcelain, gold, glass ionomer or composite) and were further classified according to the effect(s) studied (Tables 2-6).

DISCUSSION

Amalgam

There were eight studies[6-13] that examined the effects of tooth whitening on amalgam. The release of mercury ions from amalgam is a health concern. One study[6] found that more mercury and silver ions were released from admixed and spherical amalgams treated with a 16% CP gel compared to no treatment, although the amount of mercury released was reported to be within safe limits. Other studies explored the effects of HP on dental amalgam. One study[7] concluded that the release of mercury ions from dental amalgam increased with increasing concentrations of HP between 3.6%-30%. Based on the data from this study, mercury release from 37-38 amalgam restorations would be required to exceed the World Health Organisation's (WHO) maximum intake of 40µg of mercury per day. A similar study[8] found that increasing the concentration of HP resulted in a proportional increase in the release of mercury, silver, tin and copper ions from dental amalgam and concluded that there is a low likelihood of exceeding the WHO's maximum intake when concentrations of up to 10% HP are used. However, it is important to note that some tooth whitening agents contain more than 10% HP and so further research is needed to investigate the effects of these higher concentrations. Furthermore, as most studies were carried out *in-vitro*, it is possible that their findings may not be representative of the clinical conditions.

A pilot clinical trial supports the theory that the effects of tooth bleaching on mercury ion release are not harmful to health.[9] In this study mercury levels in blood, urine and saliva before and after bleaching were found to be no different. In addition, no differences were found in antioxidant enzyme activities which are a measure of the body's defence system against the free radicals released by mercury.[9]

Some authors studied the effects of bleaching agents on the physical properties of amalgam such as surface roughness. One study showed that exposure to 10% CP gel caused irregularities, cracks and pores in the surface ultramorphology of a high copper amalgam.[10]

Similarly, surface irregularities were found to be visible on a scanning electron micrograph (SEM) of amalgam treated with higher concentrations of 16% or 30% CP.[11] The surface roughness of amalgam was also found to be significantly greater after exposure to 15% CP.[12] However, unlike the other studies, this study found that the use of 10% CP did not cause an increase in surface roughness. Another study used HP instead of CP as the bleaching agent and found that there were no significant differences in surface roughness of amalgams before and after treatment with HP at various concentrations.[8] A recent literature review concluded that amalgam restorations may require replacement after whitening because the physical properties of the amalgam may be significantly and unacceptably altered.[3]

Porcelain

The effects of tooth whitening on porcelain have been were studied in nine papers.[12-20] One study[13] reported that exposure to a 38% CP home bleaching agent resulted in a surface microhardness reduction in overglazed, autoglazed and polished porcelains, and that the most significant change was observed in the polished porcelain. Interestingly, the authors stated that no special preparations could prevent these adverse effects. Furthermore, they concluded that it may be useful to protect existing porcelain restorations before tooth whitening treatments and to re-glaze or polish them afterwards. These findings support the conclusions of an earlier study[14] that suggested use of a protective barrier should be considered. These two studies differ in findings from an earlier *in-vitro* study which reported that home tooth bleaching with 15% CP caused no microhardness changes in existing polished porcelain restorations and that replacement of posterior ceramic restorations was unnecessary.[15] The conflicting results from these three studies may be explained by the different concentrations of CP which were used. Furthermore, it has previously been suggested that different environmental temperatures may explain discrepancies between studies. A study that investigated whether bleaching at 25°C and 37°C affected surface microhardness of ceramics concluded that ceramic bleached with 10% CP at either 25°C or 37°C did not display surface microhardness loss.[16] When HP is used, studies have demonstrated that there are no significant effects on the surface microhardness of porcelain for concentrations between 10% and 40%.[14,17,18] A previous literature review[3] mentioned that conventional dental ceramics are thought to be the most inert dental restorative materials, and this is supported by findings that dental ceramics remain stable whether or not they are exposed to bleaching agents.[18,19]

Alterations to colour have been observed in porcelain restorations following exposure to bleaching agents, leading some authors to conclude that they should be protected beforehand, and patients advised that a colour mismatch may be present after bleaching.[19,20]

Adverse effects on the surface roughness may be influenced by the surface preparation of the porcelain restoration. A study noted that although surface roughness was unaffected for autoglazed ceramics, it was significantly increased in a group which had been overglazed and polished.[20] The researchers attributed this difference to the removal of the overglaze layer during polishing and subsequent increased etchant effect on the exposed underlying ceramic surface.

Gold

Only two studies[21-22] were found which considered the effects of tooth whitening on gold casting alloys used as dental materials. One study reported that the surface roughness of a gold alloy was not statistically different after treatment with 10% CP compared to no treatment.[21] However, a significantly greater surface roughness was seen after the CP concentration was increased to 35%. Conversely, an earlier study study found that any differences in the surface roughness of a gold alloy were not statistically significant when concentrations of 3%, 10% or 30% HP were used.[22] These authors further reported that the release of gold ions from the alloy did not increase with increasing HP concentration. However, all other metal ions measured in the study were found to increase after bleaching.[22]

The conflicting results from these two studies may possibly be explained by the use of CP in one and HP in the other. In addition, findings may have been influenced by the lack of standardisation of methods between the studies. For example, one study applied 10% CP and 35% CP for 8 hours and 2 hours respectively,[21] whereas the other used an application time of 24 hours.[22] Moreover, both studies used fabricated gold alloy specimens *in-vitro* rather than studying the effects on existing cast gold restorations. As the results from these studies are limited, further research is necessary to examine the effects of tooth whitening on gold restorations.

Glass Ionomer

There were ten studies that looked at the effect of tooth whitening on glass ionomer type materials.[12,16,18,23-29] and changes to colour, surface microhardness, roughness,

dissolution, microleakage and staining susceptibility were the adverse effects usually studied. Some studies tested conventional glass ionomers, whilst others tested resin modified glass ionomers (RMGI). A previous literature review reported that glass ionomer's stability can be compromised by aggressive bleaching,[23] and most other studies reported significant effects on glass ionomer restorative materials following bleaching.

One study observed widespread cracking and greater roughness on scanning electron micrographs (SEM) of glass ionomer samples after bleaching with 15% CP.[24] These observations were attributed to the surface dissolution effect of the CP on the glass ionomer matrix. Another study found an increased surface roughness of glass ionomer which has been treated with either CP or HP compared to before treatment.[25] Their results corroborate with previous research where it was suggested that clinicians should consider replacing glass ionomer restorations with alternative restorative materials before tooth whitening is carried out.[12] Similarly, another study concluded that because of their vulnerability to microleakage, resin modified glass ionomer cements should not be used as filling materials prior to tooth whitening.[26] However, this is contradicted in a further study which stated that replacement of existing Class V RMGI restorations is not needed after bleaching because microleakage and marginal integrity are not significantly affected.[27] More evidence is needed to find out whether adverse effects of bleaching on glass ionomer restorations differ according to the G.V. Black's classification assigned to the restoration.

Greater surface porosity, cracking and pitting observed by some authors has been attributed to the surface dissolution effect of whitening agents. One study observed extensive cracking in their control glass ionomers as well as the experimental groups.[28] They raised an important point that glass ionomer is very sensitive to desiccation and therefore the surface cracks could have been caused by dehydration as part of SEM procedures. According to laboratory studies, glass ionomer surface and subsurface softening effects are greater at higher temperatures.[16,18] This suggests that temperature is an influencing factor on microhardness following bleaching. In contrast, one clinical trial showed an increase in surface microhardness after use of 15% CP,[29] and since this study was carried out *in-vivo*, the findings may be more representative of the clinical situation.

Comparatively less research has been carried out with respect to colour changes related to bleaching. Although colour changes were observed in one study, these were found to decrease to a clinically acceptable level after the bleaching treatment was stopped.[24] One

study assessed the effects of bleaching on staining susceptibility and found that chemically cured glass ionomers which have been bleached are more susceptible to staining.[28]

Composite

It is perhaps unsurprising that most sources from the literature search had studied the effects of tooth whitening agents on the properties of composites; including microhardness, colour, bond strength, surface roughness, staining susceptibility and microleakage. Thirty-six studies were included within this review.[10,13-15,17,20,24-53]

Conflicting results on microhardness have been reported. Following bleaching, one *in-vitro* study found a reduced microhardness for nanofilled, silorane-based and hybrid types, whilst a microhybrid composite showed no significant changes.[30] Two studies directly contradict this by reporting that the microhardness of microhybrid composites is decreased following exposure to CP.[31,32] However, several studies reported no alterations to the microhardness of various composite types following treatment with whitening agents.[14,15,17,29,33,34]

Findings of a decrease in microhardness are consistent with several additional studies.[13,14,35,36,37] Although a reduced microhardness was found, there was controversy regarding whether this is limited to the composite surface layers and can be removed with post-operative re-polishing[13,38] or if the damage extends deeper. One study observed softening of sub-surface layers and concluded that it is unlikely that post-operative polishing is sufficient to reverse the damage.[39] In addition, composite restorations should be protected with a barrier during whitening treatments to prevent exposure to the bleaching agents.[13,14] Two separate laboratory studies concluded that it was not necessary to replace composite restorations after whitening treatments.[15,17]

Researchers have drawn similar conclusions regarding the effects of tooth whitening on microleakage. Two studies concluded that microleakage of Class V composite restorations is not affected by whitening and therefore, post-operative composite restoration replacement is not needed.[27,40] However, other research suggests that it is likely that these findings only apply to Class V restorations and cannot be extrapolated to other classes of composite restorations. The use of 15% CP may increase dentinal margin microleakage of existing composite restorations and clinicians should consider post-whitening rebonding to reseal restoration margins.[26]

Some of the studies which investigated tooth whitening's effects on composites observed a lighter colour after treatment with CP or HP.[41,42] Conversely, others reported no significant changes to shade or colour stability.[24,43] Another study used different concentrations of HP and CP and reported a noticeable colour change for some concentrations but not for others.[44] However, any colour differences between baseline value and bleaching were deemed to be within a clinically acceptable range. A further study by which observed composite colour changes following bleaching came to the same conclusion.[45] It is unclear whether tooth bleaching has any effects on staining susceptibility and currently, the research on this topic is very limited. One *in-vitro* study found no effect on staining susceptibility with use of 20% CP[46] whilst another similar study found an increase following treatment with 15% CP.[28] Both studies used nanofilled resin composites and their conflicting results suggest that there is a need for further research before definitive conclusions can be made.

There is some evidence to suggest that exposure of existing composite resin restorations to whitening treatments results in a reduction in bond strength between the composite and dental tissues. One study which used concentrations of 10-20% CP found that the adverse effects on bond strength were increased at higher CP concentrations. Additionally, the authors noted that the composite to dentine bond strength was less affected than the composite to enamel bond strength.[47] As well as concentration, it seems that effects on bond strength may be dependent on the type of adhesive system used.[48]

Regarding surface roughness and surface morphology changes, a number of studies drew different conclusions. Some showed no effects on surface roughness,[18,37,42,49-53] whilst other studies reported an increase in the surface roughness.[10,20,41,43,52] One study described an irregular, porous composite surface with many cracks following 10% CP exposure.[10] Another study used 16-22% CP and 38% HP to demonstrate that surface roughness increases were small enough to be considered clinically irrelevant in cases where an optimal finish of the existing composite had been achieved.[25] These authors explained that the accumulation and composition of plaque is not affected at a surface roughness below a 200 nm threshold. However, they added that it may not be possible to achieve an optimal finish in every clinical case.

CONCLUSION

Current literature appears to show that the adverse effects of CP and HP on dental restorative materials are likely to be material dependent. There is the possibility that effects may also be influenced by other factors including the concentration of CP or HP used as well as temperature, although current evidence is limited. The majority of research to date has involved *in-vitro* laboratory studies and there is a need for more high quality, controlled *in-vivo* research before definitive conclusions can be made relating to the clinical scenario. Furthermore, current studies have used different bleaching regimes, various concentrations and experimental conditions. This lack of standardisation causes difficulty in making valid comparisons between studies and has led to conflicting results. However, despite the lack of strong conclusions related to clinical practice, there is evidence that various restorative materials may be affected to some degree during tooth whitening procedures. As a result, it would be prudent for clinicians to:

- Advise patients of the possibility of adverse changes to their existing dental restorations when undertaking tooth whitening procedures and that, in some cases, re-polishing or replacement of the restoration may be required.
- Wait for 2 weeks following bleaching before carrying out adhesive procedures

REFERENCES

1. Joiner A, Hopkinson I, Deng Y, Westland S. A review of tooth colour and whiteness. *J Dent* 2008; **36 (Suppl 1):** 2-7.
2. Tin-Oo M M, Saddki N, Hassan N. Factors influencing patient satisfaction with dental appearance and treatments they desire to improve aesthetics. *BMC Oral Health* 2011; **11(6):** 1-8.
3. Yu H, Zhang C, Cheng S, Cheng H. Effects of bleaching agents on dental restorative materials: a review of the literature and recommendation to dental practitioners and researchers. *J Dent Sci* 2015; **10(4):** 345-351.
4. Ali S A, Nadim R, Aslam K. Consequences of tooth bleaching on dental tissues and composite restorations: Literature Review. *Pak Oral Dent J* 2015; **35(3):** 493-496.

5. Li Y, Greenwall L. Safety issues of tooth whitening using peroxide-based materials. *Br Dent J* 2013; **215(1):** 29-34.
6. Kasraei S, Rezaei-Soufi L, Azarsina M. The effect of a 16% carbamide peroxide gel on mercury and silver ion release from admixed and spherical dental amalgams. *J Contemp Dent Pract* 2010; **11(6):** 9-16.
7. Al-Salehi SK. Effects of bleaching on mercury ion release from dental amalgam. *J Dent Res* 2009; **88(3):** 239-243.
8. Al-Salehi S, Hatton P, McLeod C, Cox A. The effect of hydrogen peroxide concentration on metal ion release from dental amalgam. *J Dent* 2007; **35(2):** 172-176.
9. Cakir F Y, Ergin E, Gurgan S, Sabuncuoglu S, Arpa C S, Tokgoz I, Ozgunes H, Kiremitci A. Effect of bleaching on mercury release from amalgam fillings and antioxidant enzyme activities: A pilot study. *J Esthet Restor Dent* 2014; **27(1):** 29–36.
10. Marto S, Coito C, Pequeno A, Cavalheiro A. Effect of tooth whitening on dental restorative materials. *Rev Port Estomatol Cir Maxilofac* 2012; **53(2):** 71–76.
11. Gurgan S, Kiremitci A, Yalcin F, Alpaslan T, Yazici E. Effect of carbamide peroxide treatments on the metal-ion release and microstructure of different dental amalgams. *Oper Dent* 2007; **32(5):** 476–481.
12. Zavanelli AC, Mazaro VQ, Silva CR, Zavanelli RA, Mancuso DN. Surface roughness analysis of four restorative materials exposed to 10% and 15% carbamide peroxide. *Int J Prosthodont* 2011; **24(2):** 155-7.
13. Torabi K, Rasaeipour S, Ghodsi S, Khaledi A A, Vojdani M. Evaluation of the effect of a home bleaching agent on surface characteristics on indirect esthetic restorative materials – part II microhardness. *J Contemp Dent Pract* 2014; **15(4):** 438-443.
14. Malkondu Ö, Yurdagüven H, Say E C, Kazazoğlu E, Soyman M. Effect of bleaching on microhardness of esthetic restorative materials. *Oper Dent* 2011; **36(2):** 177-186.
15. Polydorou O, Hellwig E, Auschill T M. The effect of at-home bleaching on the microhardness of six esthetic restorative materials. *J Am Dent Assoc* 2007; **138(7):** 978-984.
16. Yu H, Li Q, Cheng H, Wang Y. The effects of temperature and bleaching gels on the properties of tooth-colored restorative materials. *J Prosthet Dent* 2011; **105(2):** 100–107.

17. Polydorou O, Mönting J S, Hellwig E, Auschill T M. Effect of in-office tooth bleaching on the microhardness of six dental esthetic restorative materials. *Dent Mater* 2007; **23(2):** 153–158.
18. Yu H, Li Q, Wang Y, Cheng H. Effects of temperature and in-office bleaching agents on surface and subsurface properties of aesthetic restorative materials. *J Dent* 2013; **41(12):** 1290–1296.
19. Kara H, Aykent F, Ozturk B. The effect of bleaching agents on the color stability of ceromer and porcelain restorative materials in vitro. *Oper Dent* 2013 [E pub]. **38(1):** 1-8.
20. Zaki A A, Fahmy N Z. The effect of a bleaching system on properties related to different ceramic surface textures. *J Prosthodont* 2009; **18(3):** 223–229.
21. Mohsen C. The effect of bleaching agents on the surface topography of ceramometal dental alloys. *J Prosthodont* 2010; **19(1):** 33-41.
22. Al-Salehi S K, Hatton P V, Johnson A, Cox A, Mcleod C. The effect of hydrogen peroxide concentration on metal ion release from dental casting alloys. *J Oral Rehabil* 2008; **35(4):** 276–282.
23. Carey C M. Tooth whitening: what we now know. *J Evid Based Dent Pract* 2014; **14(Suppl 1):** 70–76.
24. Li Q, Yu H, Wang Y. Colour and surface analysis of carbamide peroxide bleaching effects on the dental restorative materials in situ. *J Dent* 2009; **37(5):** 348-356.
25. Markovic L, Jordan R, Glasser M, Arnold W, Nebel J, Tillman W, Ostermann T, Zimmer S. Effects of bleaching agents on surface roughness of filling materials. *Dent Mater J* 2014; **33(1):** 59-63.
26. Moosavi H, Ghavamnasiri M, Manari V. Effect of postoperative bleaching on marginal leakage of resin composite and resin-modified glass ionomer restorations at different delayed periods of exposure to carbamide peroxide. *J Contemp Dent Pract* 2009; **10(6):** 9–16.
27. Khoroushi M, Fardashtaki S. Effect of light-activated bleaching on the microleakage of class v tooth-colored restorations. *Oper Dent* 2009; **34(5):** 565-570.
28. Yu H, Pan X, Lin Y, Li Q, Hussain M, Wang Y. Effects of carbamide peroxide on the staining susceptibility of tooth-colored restorative materials. *Oper Dent* 2009; **34(1):** 72–82.

29. Yu H, Li Q, Hussain M, Wang Y. Effects of bleaching gels on the surface microhardness of tooth-colored restorative materials in situ. *J Dent* 2008; **36(4):** 261–267.
30. AlQahtani M. The Effect of a 10% Carbamide Peroxide Bleaching Agent on the Microhardness of Four Types of Direct Resin-based Restorative Materials. *Oper Dent* 2013; **38(3):** 316-323.
31. Briso A L, Tunas I T, de Almeida L C, Rahal V, Ambrosano G M. Effects of five carbamide peroxide bleaching gels on composite resin microhardness. *Acta Odontol Latinoam* 2010; **23(1):** 27-31.
32. Hatanaka G, Abi-Rached F, Almeida-Junior A, Cruz C. Effect of carbamide peroxide bleaching gel on composite resin flexural strength and microhardness. *Braz Dent J* 2013; **24(3):** 263-266.
33. Kwon Y H, Shin D H, Yun D I, Heo Y J, Seol H J, Kim H I. Effect of hydrogen peroxide on microhardness and color change of resin nanocomposites. *Am J Dent* 2010; **23(1):** 19–22.
34. Shafiei F, Doustfatemeh S. Effect of a combined bleaching regimen on the microhardness of a sealed methacrylate-based and a silorane-based composite. *J Dent(Shiraz)* 2013; **14(3):** 111-117.
35. Bahari M, Savadi Oskoee S, Mohammadi N, Ebrahimi Chaharom M, Godrati M, Savadi Oskoee A. Effect of different bleaching strategies on microhardness of a silorane-based composite resin. *J Dent Res Dent Clin Dent Prospects* 2016; **10(4):** 213-219.
36. Srinivasan K, Chitra S. Effects of different concentrations of bleaching agent on the microhardness of restorative materials – an in vitro study. *J Res Med Dent Sci* 2015; **3(3):** 188-193.
37. Zuryati A, Qian O, Dasmawati M. Effects of home bleaching on surface hardness and surface roughness of an experimental nanocomposite. *J Conserv Dent* 2013; **16(4):** 356-361.
38. Lima D A, De Alexandre R S, Martins A C, Aguiar F H, Ambrosano G M, Lovadino J R. Effect of curing lights and bleaching agents on physical properties of a hybrid composite resin. *J Esthet Restor Dent* 2008; **20(4):** 266-273.
39. Hannig C, Duong S, Becker K, Brunner E, Kahler E, Attin T. Effect of bleaching on subsurface micro-hardness of composite and a polyacid modified composite. *Dent Mater* 2007; **23(2):** 198-203.

40. Klukowska M A, White D J, Gibb R D, Garcia-Godoy F, Garcia-Godoy C, Duschner H. The effects of high concentration tooth whitening bleaches on microleakage of class v composite restorations. *J Clin Dent* 2008; **19(1):** 14-17.
41. De Andrade I C, Basting R T, Lima-Arsati Y B, do Amaral F L, Rodrigues J A, França F M. Surface roughness evaluation and shade changes of a nanofilled resin composite after bleaching and immersion in staining solutions. *Am J Dent* 2011; **24(4):** 245-249.
42. Gurbuz A, Ozkan P, Yilmaz K, Yilmaz B, Durkan R. Effect of at-home whitening strips on the surface roughness and color of a composite and an ormocer restorative material. *J Prosthodont* 2012; **22(1):** 69-73.
43. Mohammadi N, Kimyai S, Abed-Kahnamoii M, Ebrahimi-Chaharom M, Sadr A, Daneshi M. Effect of 15% carbamide peroxide bleaching gel on color stability of giomer and microfilled composite resin: an in vitro comparison. *Med Oral Patol Oral Cir Bucal* 2012; **17(6):** 1082-1088.
44. Hubbezoglu I, Akaoglu B, Dogan A, Keskin S, Bolayir G, Özçelik S, Dogan O. Effect of bleaching on color change and refractive index of dental composite resins. *Dent Mater J* 2008; **27(1):** 105-116.
45. Anagnostou M, Chelioti G, Chioti S, Kakaboura A. Effect of tooth-bleaching methods on gloss and color of resin composites. *J Dent* 2010; **38(Suppl 2**): 129–136.
46. Çelik Ç, Yüzügüllü B, Erkut S, Yazici A R. 2009. Effect of bleaching on staining susceptibility of resin composite restorative materials. *J Esthet Restor Dent* 2009; **21(6):** 407-414.
47. Barcellos D, Benetti P, Fernandes V, Valera M. Effect of carbamide peroxide bleaching gel concentration on the bond strength of dental substrates and resin composite. *Oper Dent* 2010; **35(4):** 463-469.
48. Dudek M, Roubickova A, Comba L, Housova D, Bradna P. Effect of postoperative peroxide bleaching on the stability of composite to enamel and dentin bonds. *Oper Dent* 2013; **38(4):** 394-407.
49. Bodanezi A, de Bittencourt M E, Bodanezi R V, Zottis T, Munhoz E A, Carlini B Jr. Surface modifications on aesthetically restored teeth following home bleaching with 16% carbamide peroxide. *Eur J Dent* 2011; **5(2):** 157-162.

50. Irawan B, Irawan S, Masudi S, Sukminingrum N, Alam M. 3D surface profile and color stability of tooth colored filling materials after bleaching. *BioMed Res Int* 2015; [E pub]. **Article no 327289:** 1-9.
51. Sharafeddin F, Jamalipour G. Effect of 35% carbamide peroxide gel on surface roughness and hardness of composite resins. *J Dent (Tehran)* 2010; **7(1):** 6–12.
52. Torabi K, Rasaeipour S, Khaledi A A, Vojdani M, Ghodsi S. Evaluation of the effect of a home-bleaching agent on the surface characteristics of indirect esthetic restorative materials: part 1 – roughness. *J Contemp Dent Pract* 2014; **15(3):** 326-330.
53. Zavanelli A C, Mazaro V Q, Silva C R, Zavanelli R A, Mancuso D N. Surface roughness analysis of four restorative materials exposed to 10% and 15% carbamide peroxide. Int J Prosthodont 2011; **24(2):** 155-7.

Table 1: Inclusion and exclusion criteria for papers in the literature review.

Inclusion Criteria	• Literature which examined the effects of tooth whitening on dental restorations or any of the following dental restorative materials: amalgam, composite, glass ionomer restorative materials, gold, porcelain • Literature from 2007-2016 • Literature from any country was included, provided that it was available in the English language • Literature which used any study design type • Both primary and secondary source types were considered • Literature was included irrespective of outcome
Exclusion Criteria	• Literature which was not written in the English language • Literature which was not accessible to the University of Bristol • Literature which was from a year outside of the period 2007-2016

Table 2: Sources which studied the effects of tooth whitening on amalgam

Reference	Effect(s) studied
Al-Salehi et al. (2007)	Surface roughness
Al-Salehi (2009)	Ion release
Cakir et al. (2014)	Ion release
Gurgan et al. (2007)	Surface roughness
Kasraei et al. (2010)	Ion release
Marto et al. (2010)	Surface roughness
Yu et al. (2015)	Physical properties
Zavanelli et al. (2011)	Surface roughness

Table 3: Sources which studied the effects of tooth whitening on porcelain

Reference	Effect(s) studied
Kara et al. (2013)	Colour change
Malkondu et al. (2011)	Microhardness
Polydorou et al. (2007a)	Microhardness
Polydorou et al. (2007b)	Microhardness
Torabi et al. (2014a)	Microhardness
Yu et al. (2011)	Microhardness
Yu et al. (2013)	Microhardness
Zaki and Fahmy (2009)	Surface roughness and colour change
Zavanelli et al. (2011)	Surface roughness

Table 4: Sources which studied the effects of tooth whitening on gold

Reference	Effect(s) studied
Al-Salehi et al. (2008)	Metal ion release and surface roughness
Mohsen (2010)	Surface roughness

Table 5: Sources which studied the effects of tooth whitening on glass ionomer

Reference	Effect(s) studied
Carey (2014)	Multiple effects (review)
Khouroushi and Fardashtaki (2009)	Microleakage and marginal integrity
Li et al. (2009)	Colour change and surface roughness
Markovic et al. (2014)	Surface roughness
Moosavi et al. (2009)	Microleakage
Yu et al. (2008)	Microhardness
Yu et al. (2009)	Staining susceptibility and surface roughness
Yu et al. (2011)	Surface microhardness
Yu et al. (2013)	Microhardness and surface roughness
Zavanelli et al. (2011)	Surface roughness

Table 6: Sources which studied the effects of tooth whitening on composite

Reference	Effect(s) studied
AlQahtani (2013)	Microhardness
Anagnostou et al. (2014)	Colour change and gloss
Bahari et al. (2016)	Microhardness
Barcellos et al. (2010)	Bond strength
Bodanezi et al. (2011)	Surface morphology
Briso et al. (2010)	Microhardness
Çelik et al. (2009)	Staining susceptibility
De Andrade et al. (2011)	Surface roughness and shade changes
Dudek et al. (2013)	Bond strength
Gurbuz et al. (2012)	Surface roughness and colour
Hannig et al. (2007)	Microhardness
Hatanaka et al. (2013)	Microhardness
Hubbezoglu et al. (2008)	Colour change
Irawan et al. (2015)	3D surface profile, surface roughness and colour stability
Khoroushi and Fardashtaki (2009)	Microleakage
Klukowska et al. (2008)	Microleakage
Kwon et al. (2010)	Microhardness and colour change
Li et al. (2009)	Colour change
Lima et al. (2008)	Microhardness
Malkondu et al. (2011)	Microhardness
Markovic et al. (2014)	Surface roughness
Marto et al. (2012)	Surface roughness
Mohammadi et al. (2012)	Surface roughness and colour stability

Moosavi et al. (2009)	Microleakage
Polydorou et al. (2007a)	Microhardness
Polydorou et al. (2007b)	Microhardness
Shafiei and Doustfatemah (2013)	Microhardness
Sharafeddin and Jamalipour (2010)	Surface roughness and hardness
Srinivasan and Chitra (2015)	Microhardness
Torabi et al. (2014a)	Microhardness
Torabi et al. (2014b)	Surface roughness
Yu et al. (2008)	Microhardness
Yu et al. (2009)	Staining susceptibility
Yu et al. (2013)	Surface roughness
Zavanelli et al. (2011)	Surface roughness
Zuryati et al. (2013)	Surface roughness and hardness

Figure 1: Prisma flow diagram of the review process.